

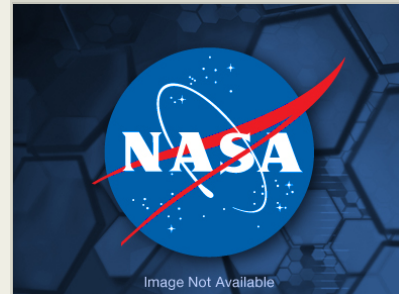
# Laboratory Study of Magnetohydrodynamic and Hydrodynamic Instabilities in Rotating Flows Relevant to Astrophysical Disks

Completed Technology Project (2015 - 2017)



## Project Introduction

Efficient dissipation of the orbital energy of plasma occurs in accretion disks ranging from those in which planets form around protostars, to those around supermassive black holes in active galactic nuclei. Two mechanisms have been proposed for the turbulence that drives dissipation and angular-momentum transport in such disks: (1) a linear instability of magnetized and electrically conducting flow known as magnetorotational instability (MRI); and (2) nonlinear hydrodynamic shear-flow instability. Two laboratory apparatuses have been constructed at Princeton to study these mechanisms. The Liquid-Metal MRI experiment is designed to study MRI and related MHD instabilities. The Hydrodynamic Turbulence Experiment (HTX) is designed to study nonlinear hydrodynamic transition. Both of these devices are novel in two respects: large Reynolds numbers ( $Re \sim 10^6$ ) and multiple independently driven rings on the axial boundaries to minimize secondary (Ekman) flows. We have demonstrated negligible angular momentum transport at  $Re \leq 2 \times 10^6$  in quasi-keplerian hydrodynamic flow with minimized Ekman circulation. This result, published in Nature, has generated significant interest among astrophysicists and fluid dynamicists. Recently, the MHD experiment has demonstrated robust nonaxisymmetric Shercliff-layer instabilities in strong axial magnetic fields. The latter result has paved a clear path towards first conclusive demonstration of MRI in the laboratory. Support is requested to continue fundamental laboratory studies with these devices. The proposed research will focus on experimental studies of the following major questions: (Q1) Why are quasi-keplerian flows resistant to turbulence? Can the turbulence found by other experiments be explained by differences in the boundary conditions or diagnostics used? Can nonlinear hydrodynamic transition occur in flow that is partially magnetized but too diffusive for MRI? (Q2) How do MRI, Shercliff-layer instabilities, and other MHD activity drive angular momentum transport? What are their saturation mechanisms? To study these questions quantitatively and conclusively, we propose the following specific improvements and additions: (1) to add crucial diagnostics for direct global torque measurements in HTX and then the liquid metal MRI experiment; (2) to measure local Reynolds and Maxwell stresses in the liquid-metal flow; and (3) to further increase and control rotation speeds by hardware improvements and possibly an additional electromagnetic drive.



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## Organizational Responsibility

### Responsible Mission Directorate:

Science Mission Directorate (SMD)

### Responsible Program:

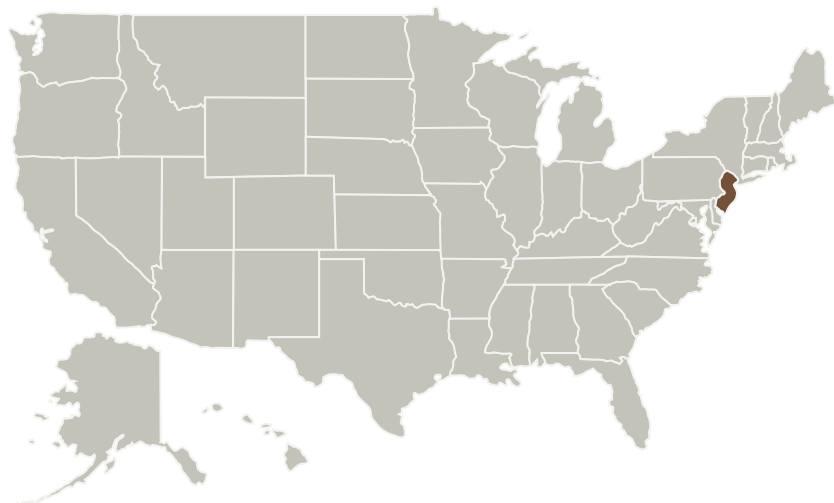
Astrophysics Research and Analysis

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## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Princeton University	Supporting Organization	Academia	Princeton, New Jersey

## Primary U.S. Work Locations

New Jersey

## Project Management

### Program Director:

Michael A Garcia

### Program Manager:

Dominic J Benford

### Principal Investigator:

Hantao Ji

### Co-Investigator:

Jeremy Goodman

## Technology Areas

### Primary:

- TX14 Thermal Management Systems
  - └ TX14.3 Thermal Protection Components and Systems
    - └ TX14.3.3 Thermal Protection Analysis

## Target Destination

Outside the Solar System